264 094

ESS REPORT

BATTELLE MEMORIAL INSTITUTE

TENTH MONTHLY PROGRESS REPORT

on

A STUDY AND EVALUATION OF LIQUID-LEVEL AND LIQUID-VOLUME CONTROLS FOR SHELL-, ROCKET-, AND BOMB-FILLING MACHINES

to

ARMY CHEMICAL CENTER

E I r 080-15/10 Cpy 6

~~May 1, 1953~~

Contract No. DA 18-108-CML-3965

by

Thomas M. Boland, William Hecox, E. C. Foudriat,
Roger L. Merrill, and Robert C. McMaster

BATTELLE MEMORIAL INSTITUTE
505 King Avenue
Columbus 1, Ohio

TABLE OF CONTENTS

TENTH MONTHLY PROGRESS REPORT

on

A STUDY AND EVALUATION OF LIQUID-LEVEL AND LIQUID-VOLUME CONTROLS FOR SHELL-, ROCKET-, AND BOMB-FILLING MACHINES

to

ARMY CHEMICAL CENTER

Contract No. DA 18-108-CML-3965

from

BATTELLE MEMORIAL INSTITUTE

by

Thomas M. Boland, William Hecox, E. C. Foudriat,
Roger L. Merrill, and Robert C. McMaster

May 1, 1953

SUMMARY

Consideration ~~is~~ given in ~~this report~~ to three liquid-control systems of filling munitions to a given level. Two of these systems employ ultrasonic techniques, and the third, an electrical-conductance probe.

The system incorporating the conductance probe has been selected for construction and development at Battelle.

A description and drawing of the improved Annin-valve-drive mechanism is also presented.

INTRODUCTION

This is the Tenth Monthly Progress Report on "A Study and Development of Liquid-Level and Liquid-Volume Controls for Shell-, Rocket-, and Bomb-Filling Machines". This report covers the work period from April 1 to April 30, 1953.

Initially, the work on this project centered on the development of a device to deposit accurate, reproducible volumes of liquid agent into munitions. This device has been constructed and is now being tested and improved at Battelle.

With this report, work is being renewed on the development of a liquid-flow system to control the agent level in the filling of munitions.

WORK IN PROGRESS

The work on this project during April consisted of:

1. Consideration of systems to accomplish accurate filling of munitions to a desired level.

2. Selection of a basic system for constant-level munition filling to be built at Battelle.

3. Further refinements to the motor-driven Annin valve.

Constant-Level Filling Systems

In this report, three systems adaptable to the filling of munitions to a given level are described. These are:

1. An electrical-conductance probe device.

2. A system using ultrasonic-pulse techniques.

3. An ultrasonic system incorporating a resonant column.

Electrical-Conductance Probe

As its principal operation, the electrical-conductance probe uses the liquid to complete the electrical circuit. Since air is a good insulating

material, a large change in resistance occurs when the probe becomes immersed in a solution of a conducting liquid.

The drawing, Figure 1, shows a probe system in which filling is controlled by two concentric probes. The first probe slows the filling rate appreciably and tends to reduce surface waves and splash which may cause filling to an erroneous level. The second probe stops the flow of liquid into the shell. The probe signals are used to control electrically actuated valves and to relay signals to the sequence-timer circuits, thereby carrying out the operation of replacing filled shells with empty ones, repeating the filling operation, et cetera.

The conductivity of the liquid sample can easily be determined by a simple test. It is believed that fill accuracy within 1/8 inch is easily obtainable with this system, as long as splash is kept to a minimum.

Ultrasonic-Pulse Techniques

One method of measuring the thickness or height of a homogeneous body is by use of ultrasonic sound energies. It has only been recently that this form of energy has been exploited for such uses.

Before discussing the block diagram of the ultrasonic-pulse device, it seems advisable to discuss the properties of ultrasonic energy as applied to liquid-level detection. A sound wave traveling through a medium is analogous to an electrical wave traveling along a transmission line. Whenever a discontinuity occurs, some energy is transmitted through the boundary and some is reflected. At a water-air boundary, most sound energy is reflected. In the sound-conducting medium, an attenuation occurs which is again analogous to the attenuation on a transmission line. The degree of attenuation depends on the medium and somewhat on frequency. The energy lost due to attenuation heats up the material through which the sound travels.

When large-amplitude sound waves are present in a liquid, another phenomenon called cavitation occurs. Cavitation can be visualized by considering that a sound wave alternately places the molecules at a given spot in compression and tension. If the sound amplitudes are great enough, the molecules are given large tensile stresses, and a tendency to rupture the liquid occurs. At this energy level, large localized heating and, in some cases, gassing and chemical changes take place. As Richardson states, "If locally the pressure is reduced to the vapor pressure cavitation ensues".[1] Thus, cavitation would definitely cause gassing. In regard to chemical decomposition, Wessler says, "It is presumed that the great energy required to break chemical bonds becomes available through either (a) friction between macromolecules and solvent, or (b) friction accompanying cavitation".[2]

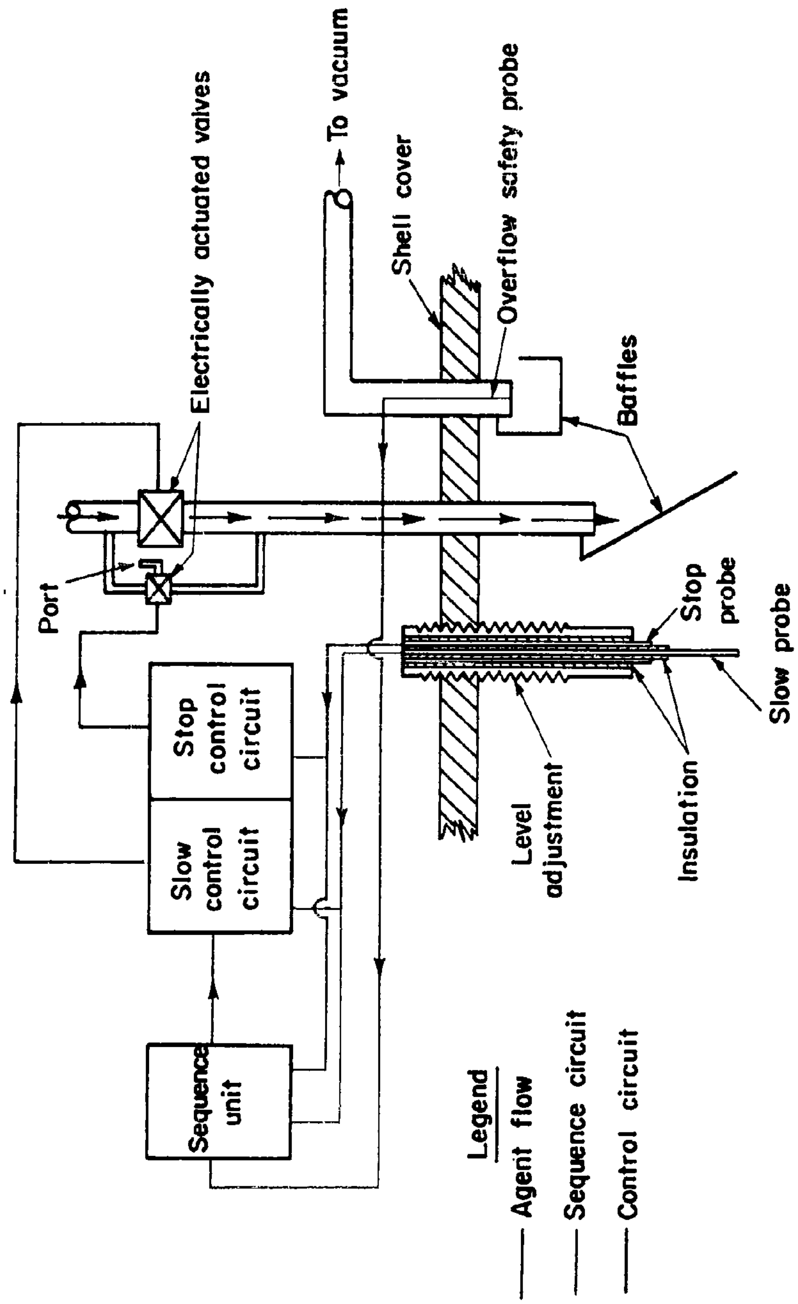

FIGURE I. ELECTRICAL-CONDUCTANCE-PROBE LIQUID-LEVEL CONTROL

A-5353

Discussions with the people working in the fields of ultrasonics and nondestructive testing at Battelle have led to qualitative conclusions that it should not be necessary to approach the cavitation-energy level for precise measurement and that the energies used should cause negligible heating of any liquid whose properties are similar to water. Theoretical calculations and some simple experiments with instruments presently available at Battelle could easily ascertain the value and the detrimental effects of ultrasonics as a means of detecting liquid levels.

The first method of employing ultrasonic energies for the detection of liquid levels uses pulse techniques analogous to those used in radar scanning systems. The pulse is transmitted, reflected, and received by the crystal. The time interval between transmission and reception is a function of the height of the liquid. This time can be compared to a standard for a given height, and the time comparison can be used to control the flow of liquid. The height can be observed continually on a monitoring oscilloscope. A diagram of the unit is shown in Figure 2.

"Resonant-Column" Ultrasonic Techniques

A "resonant-column" technique using ultrasonics comprises the third method of measuring the height of the liquid. At quarter and half wavelengths of the signal frequency, the column is resonant or antiresonant. The effect is analogous to transmission lines at multiples of a quarter wavelength in that the effect tends to change the loading as seen by the oscillator-circuit output. At this resonant point, the voltage and current both change as does the phase angle between them. Measurement of either voltage, current, or phase angle can be used to obtain an indication of the height of the liquid and also to control the liquid flow. A diagram of such a unit is shown in Figure 3.

The previous principles are being employed in ultrasonic units presently on the market. The pulse-technique unit called the Reflectoscope is made by Sperry Products, and the phase unit called the Sonizon is made by Magnaflux Corporation. These units do not have the timing and control circuits necessary to control the fill; the results are shown visually on an oscilloscope tube.

Method Selected for Development

The electrical-conductance probe method of liquid-level control has been selected for development at Battelle. The equipment for this method is not complex and can be constructed readily.

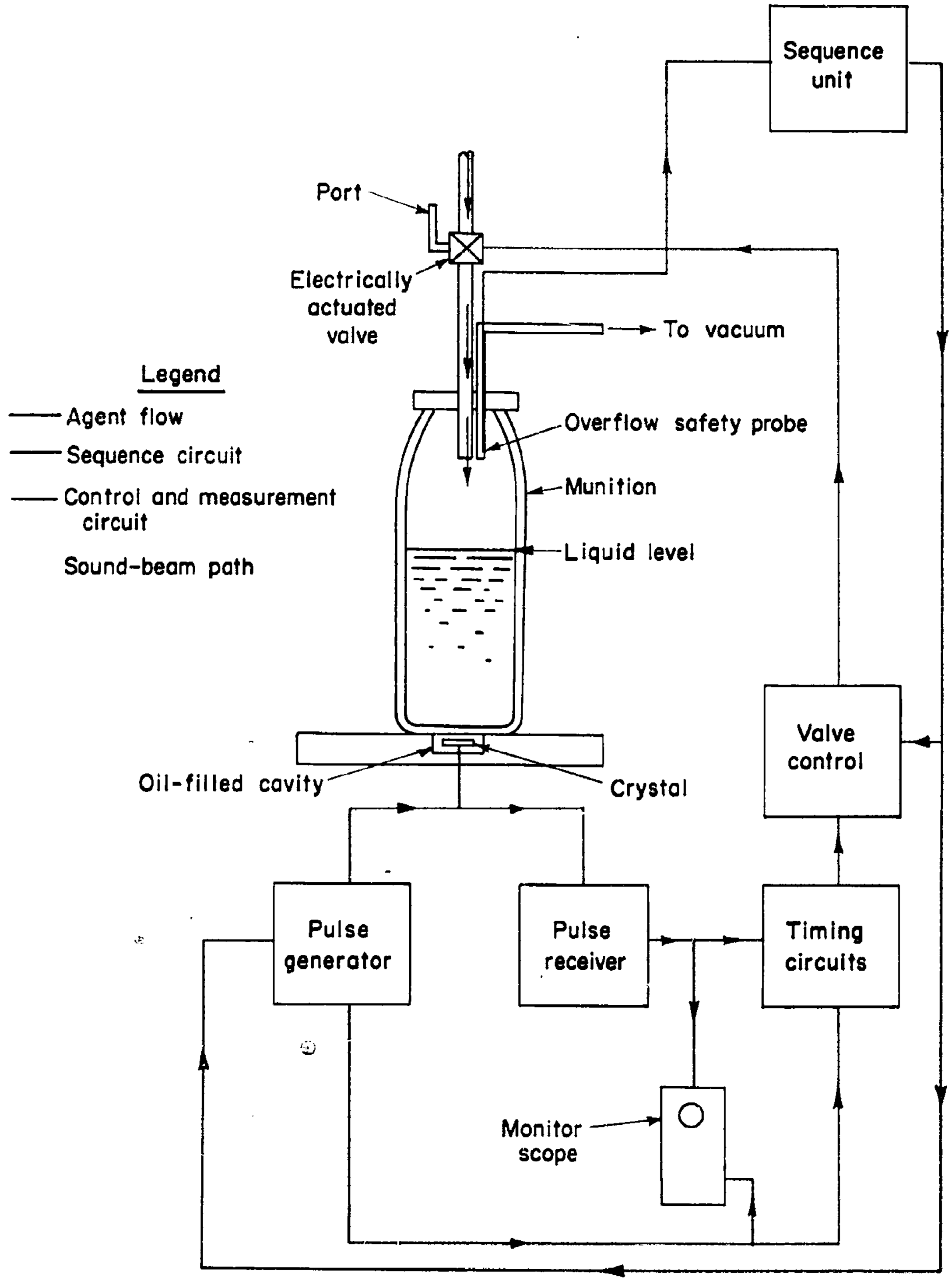

FIGURE 2. ULTRASONIC PULSE TECHNIQUE FOR LIQUID-LEVEL CONTROL

A-5354

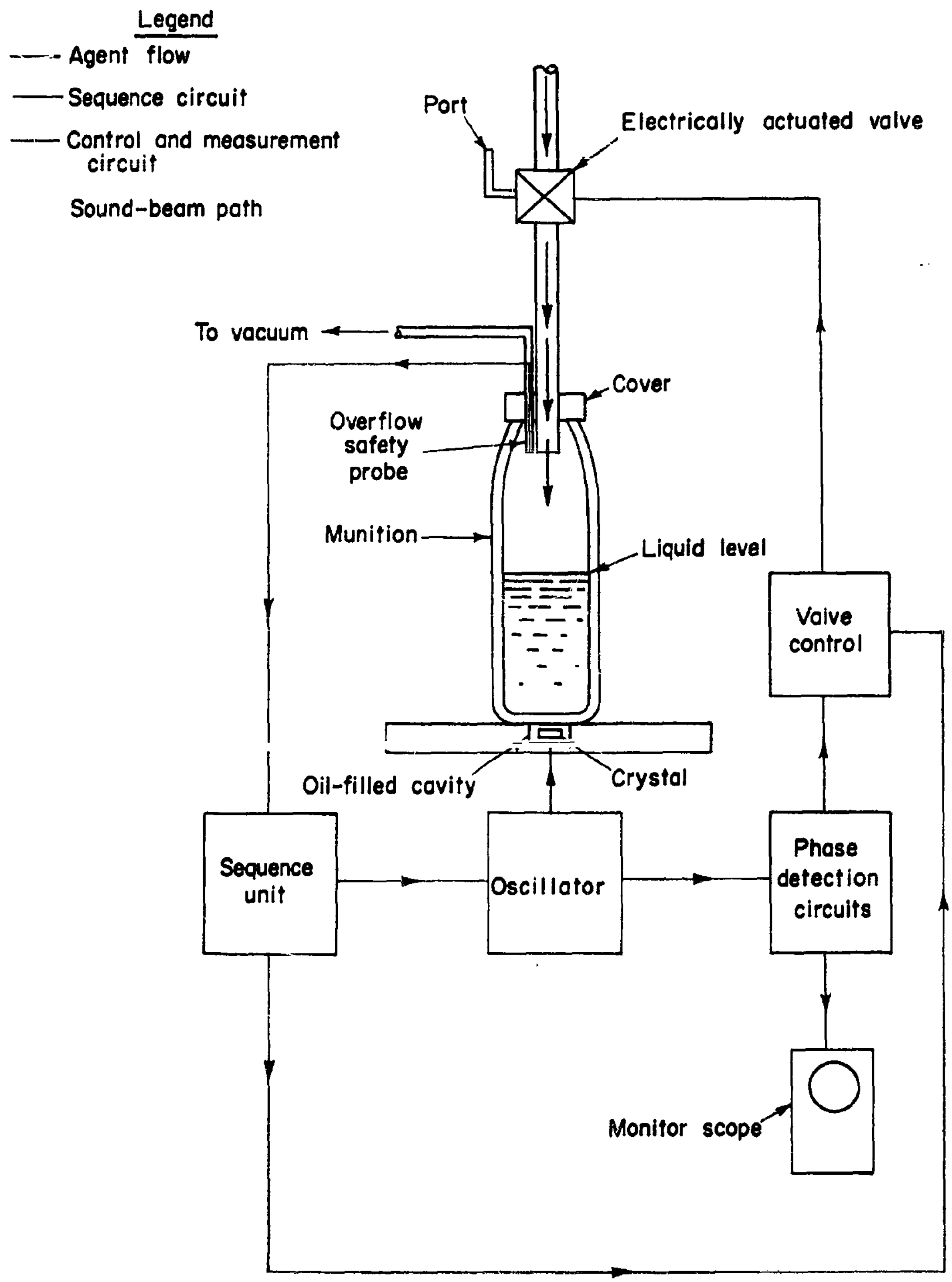

FIGURE 3. "RESONANT-COLUMN" METHOD OF LIQUID-LEVEL CONTROL

A-5355

Further Annin-Valve Improvement

The performance of the Annin-valve-driving mechanism was not entirely satisfactory during the test runs of the weigh-filling system. Further improvements on this mechanism have been completed during April, and it is expected that these will increase the control and accuracy of the constant-volume munition filler.

A cross-section drawing of the improved valve drive is shown in Figure 4.

FUTURE WORK

Future effort will be directed toward:

1. Construction of the selected level-control system.
2. Reconstructing the complete liquid-flow system for the weigh filler.
3. Improvement of the chamber-release valve.
4. Incorporating the sequence-control mechanism into the weigh filler.

REFERENCES

1. Richardson, E. G., Ultrasonic Physics, Elsevier Publishing Company, New York, p 59, (1952).
2. Weissler, Alfred, "Ultrasonics in Chemistry", Journal of Chemical Education, Vol 25, No. 1, pp 28-30, (January, 1948).

TMB:WH:ECF:RLM:RCM/blb
April 27, 1953

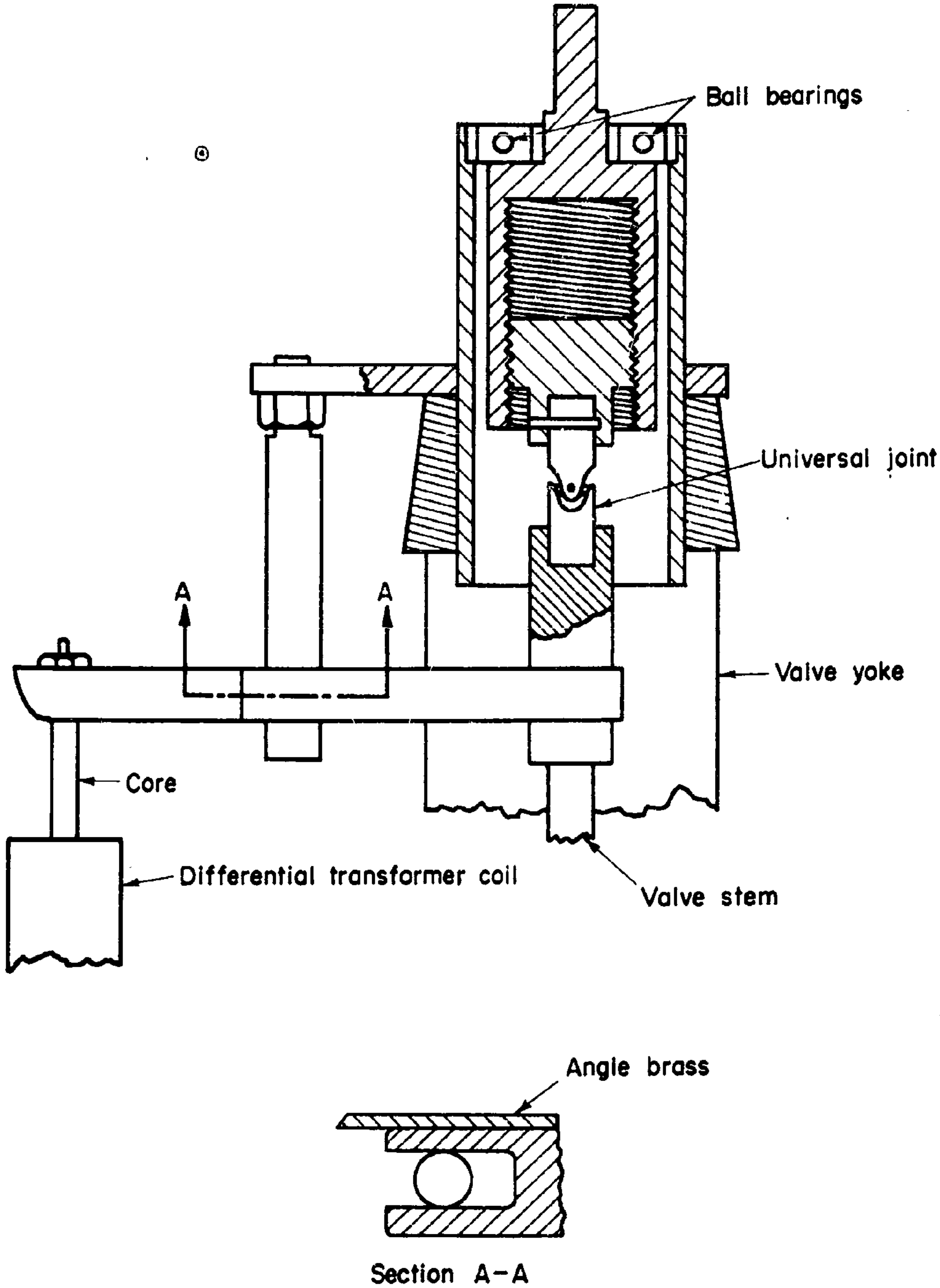

FIGURE 4. IMPROVED ANNIN VALVE DRIVING MECHANISM

A-5356

UNCLASSIFIED

UNCLASSIFIED